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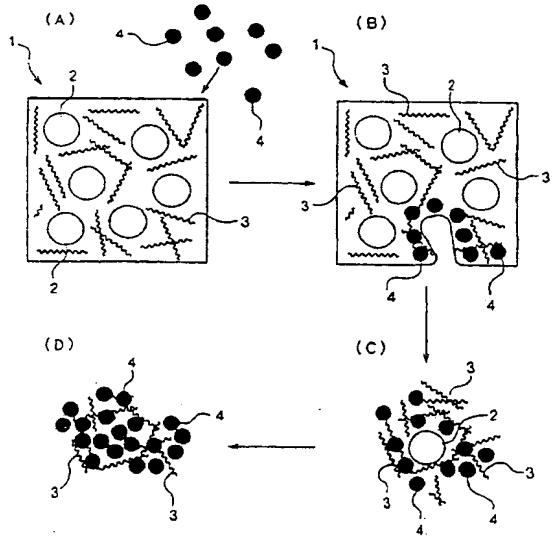
(54) Volume reducing agents for expanded polystyrene, methods and apparatus for processing expanded polystyrene using the same

(57) A volume reducing agent for processing polystyrene, consisting of 65-97 wt% of a first plasticizer having a solubility parameter less than the solubility parameter of the polystyrene; and 3-35 wt% of a second plasticizer having a solubility parameter higher than the solubility parameter of the polystyrene. The volume reducing agent is in liquid state, has the solubility parameter closed to that of polystyrene to be processed in the mixed state and transfers the resulting materials having reduced volume into gel-type products to be floated and easily separated.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a volume reducing agent for expanded polystyrene (hereinafter, referred to as EPS), methods and apparatus for processing EPS using the volume reducing agent, to thereby reduce volume of EPS known as bulky waste, as well as to recover the high quality of polystyrene out of used EPS for recycle.

Description of the Related Art

[0002] EPS known as foamed styrol has excellent thermal-protective or insulating property and buffering effect. Expanded polystyrene is used throughout the world for a variety of different purposes including, for example, but not limited to transport packaging box for sea foods and shock-absorbing packing materials contained in package for home appliances.

[0003] EPS product is generally bulky, potentially causing disposal problems. For example, burning disposal of EPS generates substantial amount of heat to cause the defect of a combustion furnace and has problems of producing harmful gases. Additional problem of EPS having bulky property(or voluminous nature) is that it occupies high transporting cost by using vehicles. Because EPS is normally soluble in some organic compounds such as aromatic hydrocarbons, hydrocarbon halides, etc., it may be attempted to design and use particular disposal plant which enables waste EPS to be dissolved. However, such plant is run on a large scale and the resulting liquid product is known to potentially derive environmental problems.

[0004] In addition, although the use of limonene capable of dissolving EPS is concerned as another disposal process, since such compound has very low ignition point of 48-Celsius degree and toxic and irritating odor, which is of undesirable property. As a result, limonene is considered an undesirable compound to be used within disposal plant with respect to safety and environmental concerns.

[0005] Due to restricted rule for clean environment in recent years, a recycling process for used EPS or methods of increasing recycling capability have been addressed as the most urgent necessity. The inventors have developed a safe and effective recycle process of EPS as a result of intensive studies to solve the aforementioned problems based on the concept to reduce the volume of EPS, rather than dissolution.

SUMMARY OF INVENTION

[0006] Accordingly, an object of the present invention is to provide a safe and effective method for volume reducing of EPS and to raise recycling capability thereof.

[0007] According to one aspect of the present invention, there is provided a volume reducing agent for processing polystyrene, consisting of a first plasticizer having a solubility parameter less than the solubility parameter of the polystyrene; and a second plasticizer having a solubility parameter higher than the solubility parameter of the polystyrene, wherein the agent is in liquid state, has the solubility parameter closed to that of polystyrene to be processed in the mixed state and transfers the resulting materials having reduced volume into gel-type products to be floated and easily separated.

[0008] According to another aspect of the present invention, there is provided a method for processing expanded polystyrene comprising the steps of: preparing a volume reducing agent, the volume reducing agent consisting of a first plasticizer having a solubility parameter less than the solubility parameter of the polystyrene; and a second plasticizer having a solubility parameter higher than the solubility parameter of the polystyrene, wherein the agent is in liquid state, has the solubility parameter closed to that of polystyrene to be processed in the mixed state and transfers the resulting materials having reduced volume into gel-type products to be floated and easily separated; dipping in the volume reducing agent an expanded polystyrene which is crushed and is in a status having a specific shape or nonspecific shape to thereby reduce the volume of the expanded polystyrene; and dipping the volume-reduced expanded polystyrene in a neutralization solution to thereby obtain recycled polystyrene material.

[0009] According to still another aspect of the present invention, there is provided an apparatus for processing expanded polystyrene by using a volume reducing agent. The apparatus comprises: a main vessel in which the volume reducing agent is under-filled and precrushed expanded polystyrene in shape or shapeless states are permeated into the volume reducing agent; and an entrapping device for soaking the expanded polystyrene into the volume reducing agent and entrapping the expanded polystyrene in a gel type in floating state.

[0010] It is to be understood that both the foregoing general description and following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claime.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the accompanying drawings:

Figure 1 illustrates the volume reducing process orderly performed by an embodiment according to the present invention using volume reducing agent;

Figure 2 is a plant view showing an embodiment of the present invention;

Figure 3 is a cross-sectional view illustrating the embodiment of an entrapping device;

Figure 4 is a cross-sectional view illustrating another embodiment of an entrapping device; and
Figure 5 illustrates the volume reducing process to reduce volume of EPS and to recover or recycle only pure polystyrene by using volume reducing agent of an embodiment according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] In order to accomplish the above captioned object, the present invention involves a volume reducing agent for processing EPS having solubility parameter closed to one of polystyrene. The solubility parameter of polystyrene varies from 8.5 to 10.3 $(cal/cm^3)^{1/2}$ at the room temperature and atmosphere pressure, based on the Ferdor definition. The volume reducing agent is prepared by blending a first plasticizer having solubility parameter less than that of polystyrene by 1-3 $(cal/cm^3)^{1/2}$, that is, having higher solubility and a second plasticizer having the solubility parameter higher than that of polystyrene by 1-3 $(cal/cm^3)^{1/2}$, that is, having lower solubility.

[0013] Also, the present invention relates a method for processing the EPS capable to be re-used, the method comprising permeating(or infiltrating) EPS materials in shape or shapeless states prepared by preliminary crushing treatment into the volume reducing agent, then soaking the result product into neutralizing solution(or counteragent solution) to obtain the re-usable polystyrene product to be easily changed into polystyrene virgine.

[0014] Furthermore, the present invention involves an apparatus for processing EPS by using the reducing agent. The apparatus includes an under-filled vessel in which reducing agent is under-filled and pre-crushed or pulvarized EPS in shape or shapeless states can be permeated into the reducing agent, and a device for entrapping EPS in suspended state the role of which soaks EPS into reducing agent within the main vessel and reduces the volume of EPS for certain period, then entraps EPS in gel state.

[0015] A preferred embodiment of the present invention will be hereinafter explained with reference to the appended Fig. 1 and Fig. 2, which, however, are not intended to be limiting of the present invention.

[0016] The present inventors took a notice to the characteristics of organic solvent having, though they can not serve to fully dissolve polystyrene based organic materials, the solubility parameter closed to the sufficient level to dissolve said organic materials to be loose and promote the volume reduction and the plasticizing reaction of said organic materials, especially EPS. In other words, it was practically found out that the gelling or plasticizing reaction of polystyrene-based organic materials, despite of non-dissolving the materials, can be accomplished by mixing the first plasticizer of the improved affinity to organic polymers and serving to loosen polymer chains by the penetration of the plasticizer into molecules of polymers and the second plasticizer of the lower affinity to organic polymers and serving to contract and/or coagulate (or condense).

[0017] Accordingly, a volume reducing agent of the present invention has the solubility parameter ranged from 8.3 to 10.3 $(cal/cm^3)^{1/2}$ closed to that of polystyrene to be applied as it is in blending state by blending the first plasticizer having solubility parameter less than that of polystyrene, that is, having higher solubility and the second plasticizer having solubility parameter more than that of polystyrene, that is, having lower solubility.

[0018] The first plasticizer includes but not is limited to dicarbonate diesters such as diethyl adipate, dimethyl adipate, dimethyl glutarate, dibuthyl adipate, dimethyl succinate, di-n-propyl adipate, diisopropyl adipate and the like, and carbonate esters such as ethyl acetate, n-propyl acetate and the like which may be selectively used alone or in admixture thereof. Hydrocarbon based solvents such as benzen, toluene, xylene, decaline, cyclohexane and the like may be used as in combination with alkyl alcohol and isoalkyl alcohol existing in liquid state at normal temperature as the solvents to which polystyrene cannot be dissolved, depending on the composition thereof.

[0019] The second plasticizer used in the present invention includes but is not limited to alkylolamines existing in liquid state at normal temperature without dissolving polystyrene such as one, two and three substituents for nitrogen group of amines. Examples of such amines includes but are not limited to triethanolamine, trimethanolamine, diethanolamine and the like, and solvents consisting of alcohols such as ethylene glycol, diethylene glycol, ethylene glycol monomethylether and the like, and esters such as r-butyrolactone, ethylene carbonate, dimethyl phthalate and the like may be used alone or in admixture thereof.

[0020] Such prepared volume reducing agent is applied to EPS 1 in coagulated state illustrated in Fig.1A. The polystyrenel contains large amount of bubble 2 and polymer ingredient 3 and reducing agent 4 applied to polystyrene 1 is penetrated within polystyrene 1 and serves to force polymer ingredient 3 outward and extend due to the action of the first plasticizer as shown in Fig. 1B, and simultaneously to contract and condense polymer ingredient 3 by the effect of the second plasticizer to derive the collapse of bubbles 2 as shown in Fig.1C. Finally, EPS 1 after completed the gelling or plasticizing process can be reduced in by volume reducing agent 4 as shown in Fig.1D.

[0021] In addition, as the result of testing different compounds as the first and second plasticizers to be selectively combined together to produce volume reducing agent, it was found that dicarbonate diester such as dimethyl glutarate (having solubility parameter of 9.75), dimethyl adipate (having solubility parameter of 9.64), dimethyl succinate (having solubility parameter of 9.88)

and the like may be most preferably used as the first plasticizer having solubility parameter closed to that of polystyrene to be applied (see the following definition).

<Definition 1>

[0022] 10.1 $(Cal/cm^3)^{1/2}$, 17.5 $MPa^{1/2}$ for commonly used polystyrene for packing material.

[0023] The solubility parameter of polystyrene actually varies from 8.56-10.3 $(cal/cm^3)^{1/2}$ or 17.4-20.1 $(mPa)^{1/2}$ for different applications due to easy variation of polymer structure.

[0024] Likewise, it was also found that the most efficient compounds as the second plasticizer of the present invention were ethylene glycol (solubility parameter 14.8) and triethanolamine (solubility parameter15.6). The solubility parameter defined herewith was the value calculated by Ferdors's method and may be slightly changed, based on the adapted parameter values at the condition of temperature and pressure.

[0025] Among different solvents previously described, it is still further preferable to use solvents of the solubility parameters ranging from 8.0 to 10.5 as the first plasticizer. Example of such solvents includes but is not limited to diethyl phthalate(10.0), dimethyl sebacinate (9.48), diethyl sebacinate(9.4), tricresyl phosphate(9.7), epoxin stearate(9.7), butyl oleate(9.5), ethylene glycol diacetate(10.0) and the like.

[0026] Likewise, as the second plasticizer the solvents having solubility parameter of at least 10.5 such as dimethyl phthalate(10.9), diethylene glycol(12.6), ethylene carbonate(14.7) are still further preferably used in the present invention.

[0027] From the result of another test for the above plasticizers, it was understood that the volume reducing agent consisting of the first and second plasticizers enables negative ions, certain forms of tourmaline and vibration of supersonic wave to enhance or promote infiltration and separation of EPS.

[0028] Turning to the drawing, the exemplary embodiment of the method and apparatus for using the volume reducing agent for EPS are explained with reference to the accompanying drawings.

[0029] Referring to Fig. 2, there is shown a processing apparatus 5 comprises a main vessel 6, a neutralization vessel 7, a conveyer means 8 and a crusher 9. Within the main vessel bath 6, the volume reducing agent 10 for EPS is filled and pre-crushed or pulvarized EPS or EPS in shape or shapeless state 1 are successively added.

[0030] The main vessel 6 is equipped by a rotation device 11 for agitating the agent 10 to accelerate the process. Other than the rotation device 11, the supersonic wave vibrator can be also used as agitation means. Such vibration means do not only enhance and promote the volume reduction process, but also separate the foreign material out of EPS. It is further preferable to add alternative means such as ion generator and tourmaline and the like. Drain valve 12 attached to the main vessel 6 can be opened to drain and discard impurities such as separated and precipitated ink or soil.

[0031] EPS 1 put into the main vessel 6 is permeated into the agent 10 and gradually reduced in volume. As seen in Fig. 2, EPS 1 provided into the left side of the main vessel 6 is delivered to the right side of the same bath and reduced in volume for a certain time period, thus the resulting volume-reduced EPS 1 passes through and is entrapped by the entrapping device 13.

[0032] The above entrapping device 13 comprises a screw feeder and sieve 14 for picking-up EPS 1 reduced in volume which is floating at the right side of the vessel 6, the squeezed and processed EPS 1 being continuously provided to the neutralization vessel 7.

[0033] In the neutralization vessel 7 filled with counter agent 15 (neutralizing solution) processed EPS 1 is infiltrated into the neutralizing solution 15. Such solution, for example, the water solution containing 0.01% chlorine or 0.1% hydrogen peroxide prevents the further promotion of gelling or plasticizing reaction of EPS 1 already reduced in volume and enables the EPS 1 to be solidified.

[0034] As described above, EPS 1 entered into the vessel 7 passes from the left direction through the right direction of Fig.2 under floating state and is solidified, and discharged from the vessel 7 and is then delivered by the conveyor means 8, while being dried out to the crusher 9. Such crusher 9 breaks up EPS 1 into fine pieces and enables the fine pieces to be provided into the bucket 16. Even though not shown, the crusher 9 may be replaced with compression device to change the process EPS into pellet, cables or sheets.

[0035] Accordingly, finely pieced EPS 1 in the bucket 16 is capable of re-used as a recycled polystyrene product so that the efficient recycling of synthetic resin sources is accomplished by the present invention.

<EXAMPLE 1>

[0036] Referring to Fig. 3, it shows the simplified embodiment of the entrapping device used in the present apparatus.

[0037] The main vessel numbered 6 is filled with the volume reducing agent 10, the numeral 7 being given to the neutralization vessel for underflowing the neutralizing solution. EPS 1 reduced in volume which is floating along the arrow direction in the bath 6 may be picked up by a meshed sieve 17 which intermittently swing oer to the "A," then being successively thrown into the vessel 7. The details on the rest part of the configuration of the process apparatus 5 arranged in the same manner as shown in Fig. 2.

<EXAMPLE 2>

[0038] Fig. 4 shows another modified and more de-

veloped embodiment of the entrapping device used in the present apparatus.

[0039] Such entrapping device comprises an aspiration device 18 for sucking EPS 1 reduced in volume which is floating along the arrow direction in the bath 6, the device 18 being capable of delivering sucked EPS 1 from the bath 6 to the neutralization vessel 7. The details for other construction parts of the process apparatus 5 arranged in the same manner as shown in Fig. 2 except that mentioned above may not be.

[0040] Fig. 5 shows that a preferred embodiment of the system for processing EPS and producing higher quality polystyrene from the EPS.

[0041] Used EPS is usually stained with dirt or adhered by paper or adhesive tape. Such impurities act as an unfavorable factor to lower the quality of EPS reduced in volume, leading to lower the value of final products. Therefore, such impurities may be removed by human labor before processed. Apart from the expenses problem, it has an important disadvantage that the removal of such impurities in used EPS to meet the level of final product to sufficiently be recycled for new EPS is practically impossible. However, with the embodiments of the present invention, it may be possible to remove impurities to the highest level and to reduce the volume of EPS without additional labor costs. This results in the rise of the value of the final product to be recycled as the raw material to make new EPS because of having higher purity and the advantage of reducing the volume of EPS without changing molecular structure of polystyrene.

[0042] Returning to Fig. 5, it is seen that the processing operation is initiated by the placement of used EPS into a hopper 101. If such EPS was heavily contaminated by dirt or the like, it may need to be washed before thrown into the hopper 101.

[0043] A first crusher 102 driven by a motor serves to primarily break the chunk of EPS and to feed them to a second crusher 103, where the pre-treated EPS are crushed into smaller pieces of desired particle size. The first crusher 102 has the blades of wider gaps between themselves, bigger outside diameter and lower rotating speed than the second crusher 103, leading to accomplish the maximum efficiency of electricity permitting pulverizing efficiency and uniform torque of the second crusher 103. On the contrary, the second crusher 103, in which the blades rave smaller gaps between blades, smaller outer diameter and higher rotating speed than the first crusher 102 does, serves to break up EPS in desirable particle size, depending on the reaction time of the volume reducing agent for EPS. The second crusher 103 may comprise a certain type of cutter or mill positioned. Pulverized pieces from the secondary pulverizing process have about 10 mm in size, though it depends upon the performance of reducing agent solution.

[0044] As a rule, pulverized EPS particles are reduced in volume due to transferring from solid floating to gel state by the volume reducing agent solution. To increase the reducing-volume rate and to produce the flow rate causing the movement of EPS toward a screw 106 may be achieved by immersing the blades of second crusher 103 into reducing agent solution to generate strong whirlpool. Such whirlpool increases the reducing rate, the stream of fluid flows along a path 105, and the floating polystyrene flows into the screw 106, is compressed and transported into a chopper 112. In order to increase the reaction rate within this area, vibration of ultrasonic or injection of reducing agent solution may be adapted to the present invention. Screw 106 vertically positioned on a main vessel 104 can decrease the solution content, that is, the ratio of the reducing agent solution existed in processed EPS of reduced volume, to the maximum level by increasing the pressure at the outlet of the screw 106 much as possible. In case of square shaped main vessel, resistance due to the right-angled flow reduce the flow rate. Such resistance may be minimized by using donut-like main vessel having wider pulverizing area and narrower screw 106 area in order to lower flow resistance of flow produced by blade rotation in minimal.

[0045] To remove impurities, at the same time of reducing volume of EPS solution, the second crusher 103 generates bubbles by means of additives, if required, to agent solution. Through a bubble removal path 108, it is possible to remove dirt including dust and other floating impurities. Such agent solution is circulated by a pump 109 equipped to the main vessel 104 which is streamline-shaped along the path 105, passes through a filter 110, which removes floating materials or water existed in reducing agent solution. Bubble removal path 108 may be of the simple structure and can use paper or cotton textile. Materials of heavier density than the reducing agent solution or separated by ions are collected at the bottom of main vessel 104 to a certain amount, and then drawn off throng a valve 111.

[0046] The chopper 112 is for extracting polystyrene only as the flake shape out of the floating jellified EPS by means of specific solvents having the affinity to reducing agent solution. Alternatively, a motor-driven chopper blade 114 is to increase the extraction rate of PS by means of affinity solvent, while the jellified EPS is cut to finer pieces. At the outlet of chopper 112, the mixture composed of fully extracted polystyrene having fine particles, affinity solvent and agent solution is discharged, the polystyrene being filtered by a mesh type conveyor 116 and the rest solution is extracted downward and collected into a mixed solution bath 118. In order to minimize the amount of affinity solvent injected and to reduce the load of motor, multiple of ports for supplying solvent are arranged between inlet and outlet parts of the chopper 112. It is preferable to reduce the amount of the agent solution remained on polystyrene filtered by the mesh type conveyor 116 to the lowest level by rising with the solvent. Such used solvent (containing trace of the reducing agent) is temporarily stored in

an affinity solvent bath 119 and then re-supplied into the chopper 112. Optionally, the filter 110 can remove impurities. Furthermore, the mixed solution collected in the bath 118 is transported toward a distillation tower 125 in order to implement the purification process to obtain purified reducing agent solution. The resulting polystyrene separated from the mixed solution successively rinse through an affinity solvent nozzle 117 on polystyrene, are collected into a polystyrene hopper 120, dried in a dryer 121, and finally stored in a product reservoir 122. Such stored raw material may be transferred into the form of ingot through the extrusion process.

[0047] The discharged solution from the mixed solution bath 118 passes through a heat exchanger 124 and is preheated before flowing into the tower 125 and separated into the solvent vapor and the liquid solution of reduction agent within the tower 125, the solvent vapor rising toward top part of the tower while the liquid flowing into a reboiler 132 positioned at the bottom part of the tower 125. Such vapor is condensed into the liquid solvent of affinity to solvent within a condenser 126, fed to an affinity solvent tank 129, and the stored solvent is delivered again to the chopper 112 in order to remove polystyrene from jellified EPS by using a pump 130. Loss of solvent due to the distillation process can be supported in an affinity solvent reservoir 131. Uncondensed vapor in the condenser 126 may be directly discharged into or, after the aspirating process by a vacuum pump 127, be released into the surrounding atmosphere.

[0048] Moreover, liquid entered into the reboiler 132 is under heating process to allow the residual affinity solvent components to be vaporized and returned back to the tower 125, while the rest and high purity reduction agent solution may be transported into a solution tank 134. Stored solution can be recycled by using a solution recycle pump 133 to the main vessel 104 to reduce the volume of EPS.

[0049] As aforementioned in detail, it is apparent, according to the present process and apparatus for using the volume reducing agent, that the volume of used EPS is simply reduced or used EPS may be recycled to the new material for the high quality of new EPS.

[0050] Therefore, it is understood that EPS having remarkable reduced volume produced by the present invention can be conveniently and simply stored or transported to any desire sites. It is also possible to provide any temporary treatment installations without occupying substantial space. Additionally, it will be evident that the present invented process and apparatus has environmentally advantageous because the recycling process of used EPS for new EPS may be realized.

[0051] As compared to conventional prior arts, the present invention can provide a safe and improved recycling process for EPS based organic materials without generating toxic gas (for example, limonene). The present invention has multiple the advantages to simply reduce the volume of used EPS on the actual location and, because of the easy storage and transportation thereof, to noticeably save transporting and storage expenses . Accordingly, the present invention may be a solution to social problems in connection with landfill space for waste, traffic and air pollution due to the transportation of waste.

[0052] Additionally, as the result of performing the present invention, it is possible to easily produce polystyrene products having plasticity and use these products, leading to the production costs for manufacturing a lot of parts such as electronic appliances to be greatly saved. Moreover, it is also possible to effectively utilize petroleum resources by recycling used polystyrene.

[0053] As previously discussed, the present invention provides a safe and efficient method and apparatus to reduce the volume of EPS and to raise the recycling capacity thereof.

[0054] It will be apparent to those skilled in the art that various modifications and variations of the present invention can be made without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

Claims

1. A volume reducing agent for processing polystyrene, consisting of a first plasticizer having a solubility parameter less than the solubility parameter of the polystyrene; and a second plasticizer having a solubility parameter higher than the solubility parameter of the polystyrene, wherein the agent is in liquid state, has the solubility parameter closed to that of polystyrene to be processed in the mixed state and transfers the resulting materials having reduced volume into gel-type products to be floated and easily separated

2. The volume reducing agent of claim 1, wherein the first plasticizer has an amount of 65-97 weight % and the second plasticizer has an amount of 3-35 weight %, wherein the first plasticizer has a solubility parameter less than that of the polystyrene by 1-3 $(cal/cm^3)^{1/2}$, and the second plasticizer has a solubility parameter higher than that of the polystyrene by 1-3 $(cal/cm^3)^{1/2}$, wherein the solubility parameter of the polystyrene varies between 8.5 $(cal/cm^3)^{1/2}$ and 10.3 $(cal/cm^3)^{1/2}$, wherein the solubility parameter is calculated at the room temperature and atmosphere pressed, based on Ferdor method

3. The volume reducing agent of claim 1, wherein the first plasticizer is one or more compound selected from dicarbonate diesters comprising diethyl adipate, dimethyl adipate, dimethyl glutarate, dibuthyl adipate, dimethyl succinate, di-n-propyl adipate,

and diisopropyl adipate, carbonate esters comprising ethyl acetate and n-propyl acetate, and a nonpolar hydrocarbon comprising benzen, toluene, xylene, decaline, and cyclohexane as the solvents solvent mixed with alkyl alcohol and isoalkyl alcohol existing in liquid state, wherein the first plasticizer dissolves polystyrene

4. The volume reducing agent of claim 1, wherein the second plasticizer is one or more compound selected from the group comprising alkylolamine group, alchol group, and ester group, wherein the alkylolamine group is in liquid state at room temperature without dissolving the polystyrene, wherein the alkylolamine group comprises primary, secondary and ternary substituents coupled to nitrogen group of amines and is one or more compound selected from the group consisting of triethanolamine, trimethanolamine, diethanolamineh, wherein the alchol group is one or more compound selected from the group consisting of ethylene glycol, diethylene glycol, and ethylene glycol monomethylether, wherein the ester group is one or more compound selected from the group consisting of r-butyrolactone, ethylene carbonate, and dimethyl phthalate.

5. The volume reducing agent according to claim 1, further comprising negative ions or 0.01-10 wt% of tourmalines in the agent for enhancing the clustering reaction of solution molecules.

6. The volume reducing agent according to claim 1, further comprising of less than 2 wt% of a surface active agent to generate bubbles to remove floating particles of dust.

7. The volume reducing agent according to claim 5, wherein said tourmaline has a powder form, a sphere form or a nonspecific shape, wherein the sphere form and the nonspecific shape tourmalines have 30mm or less in size.

8. A method for processing expanded polystyrene comprising the steps of:

preparing a volume reducing agent, the volume reducing agent consisting of a first plasticizer having a solubility parameter less than the solubility parameter of the polystyrene; and a second plasticizer having a solubility parameter higher than the solubility parameter of the polystyrene, wherein the agent is in liquid state, has the solubility parameter closed to that of polystyrene to be processed in the mixed state and transfers the resulting materials having reduced volume into gel-type products to be floated and easily separated;

dipping in the volume reducing agent an expanded polystyrene which is crushed and is in a status having a specific shape or nonspecific shape to thereby reduce the volume of the expanded polystyrene; and

dipping the volume-reduced expanded polystyrene in a neutralization solution to thereby obtain recycled polystyrene material

9. The method of claim 8, wherein the volume reducing agent further comprises negative ions or 0.01-10 wt% of tourmalines in the agent for enhancing the clustering reaction of solution molecules.

10. An apparatus for processing expanded polystyrene by using a volume reducing agent, claimed in claims 1 to 4,

said apparatus comprising: a main vessel in which the volume reducing agent is under-filled and pre-crushed expanded polystyrene in shape or shapeless states are permeated into the volume reducing agent; and an entrapping device for soaking the expanded polystyrene into the volume reducing agent and entrapping the expanded polystyrene in a gel type in floating state.

11. The apparatus of claim 10, further comprising an agitating means equipped within said main vessel.

12. The apparatus of claim 10, wherein said entrapping device comprises a meshed sieve or screw feeder to pick-up the expanded polystyrene reduced in volume and in floating state.

13. The apparatus of claim 10, wherein said entrapping device comprises an aspiration device for sucking the expanded polystyrene having reduced volume and in floating state.

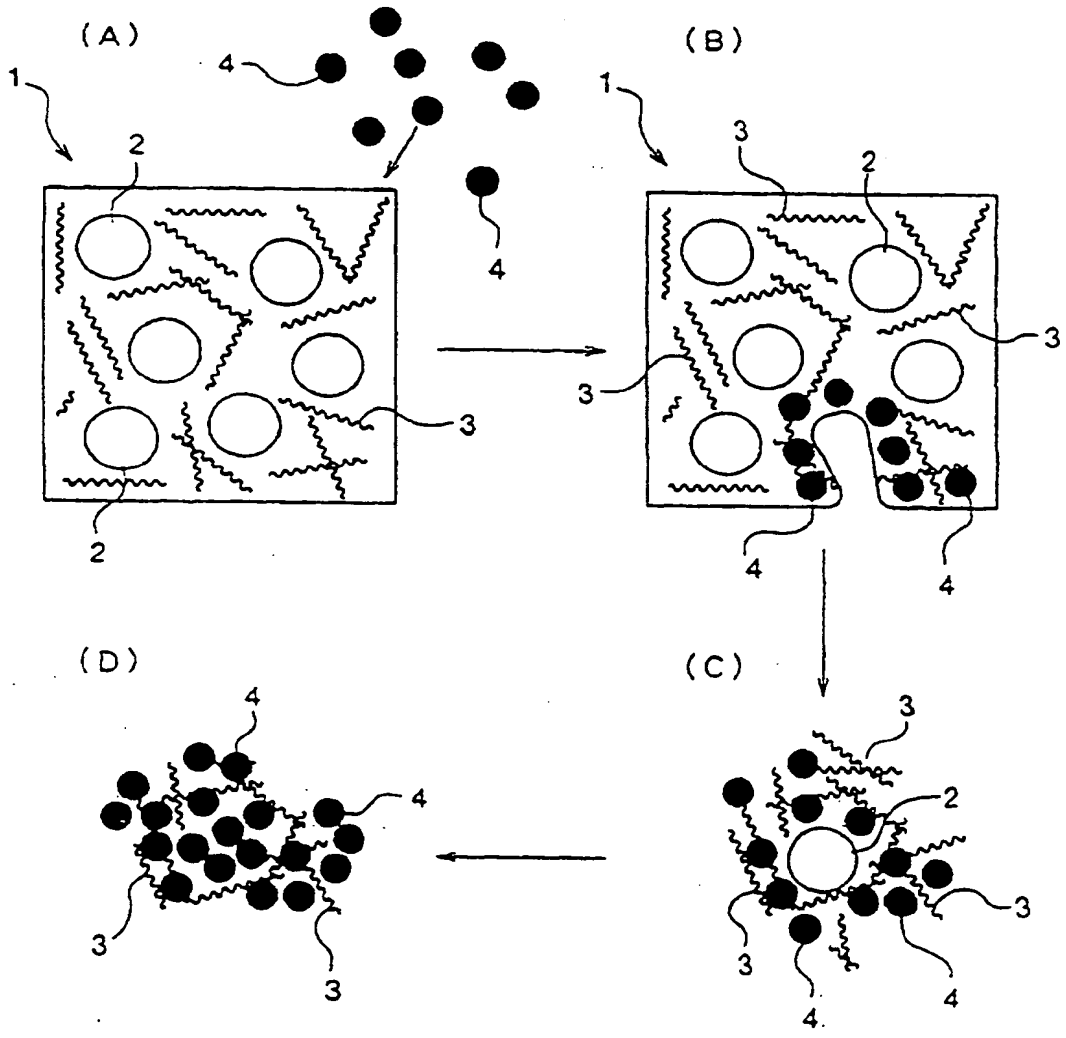
14. The apparatus of claim 10, further comprising an extracting device for polystyrene out of used expanded polystyrene by being pulverized, soaked, and reducing the volume thereof to lower the solution content that is the weight ratio of the volume reducing agent existed in get-type expanded polystyrene having reduced volume and extracting the polystyrene by blending with the solvent having affinity to the polystyrene.

15. The apparatus of claim 14, further comprising: a separation device for separating different impurities; a bubble entrapping device for removing fine floating materials generated by bubble; a filter means for removing dirt or water of specific gravity closed to the solution; and a discharging means for releasing the settled materials caused by the action claimed in claim 4.

16. The apparatus of claim 14, further comprising a dis-

tillation and filtering device for recycling the affinity solvent and the volume reducing agent.

FIG. 1



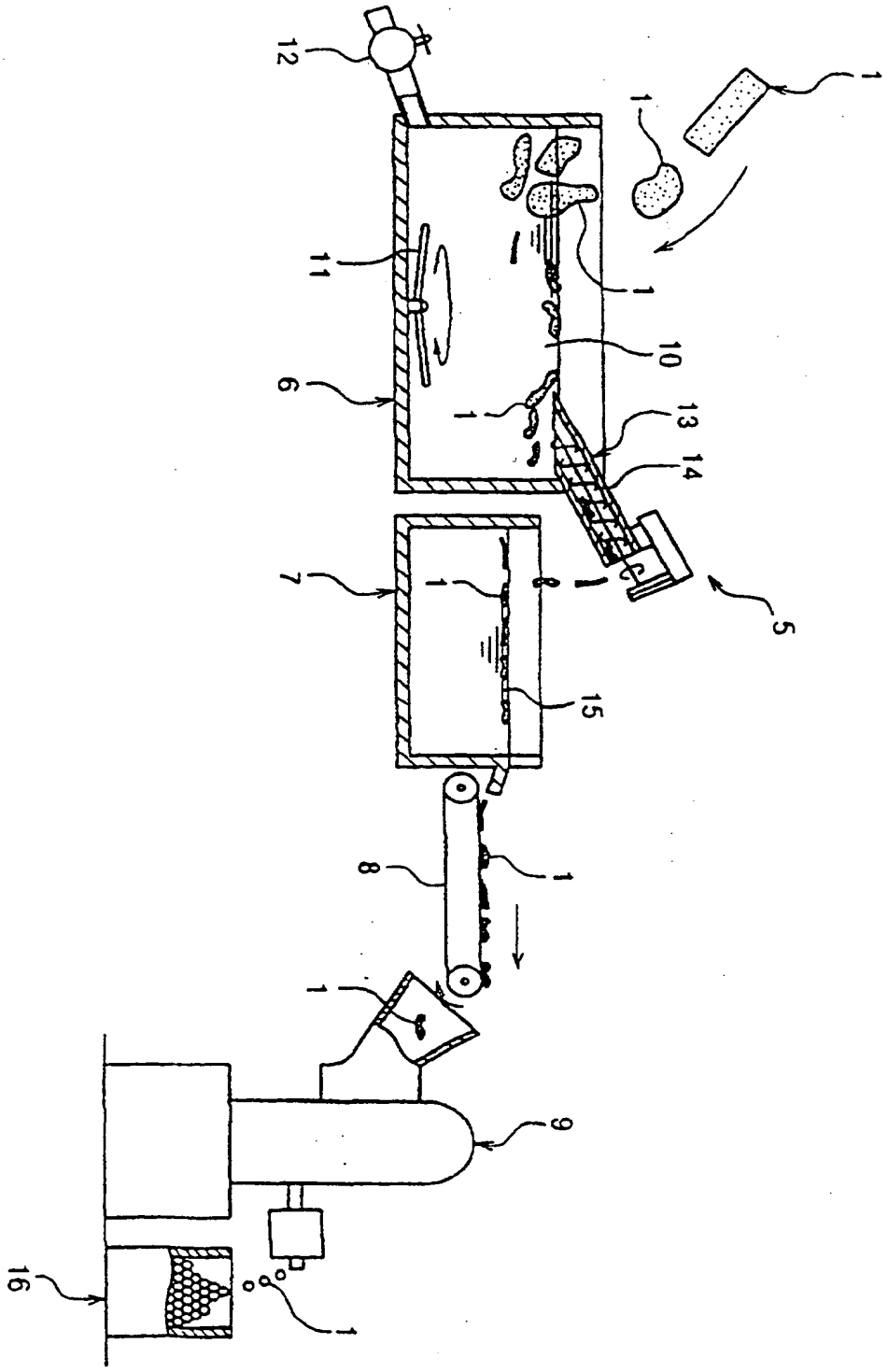


FIG. 2

FIG. 3

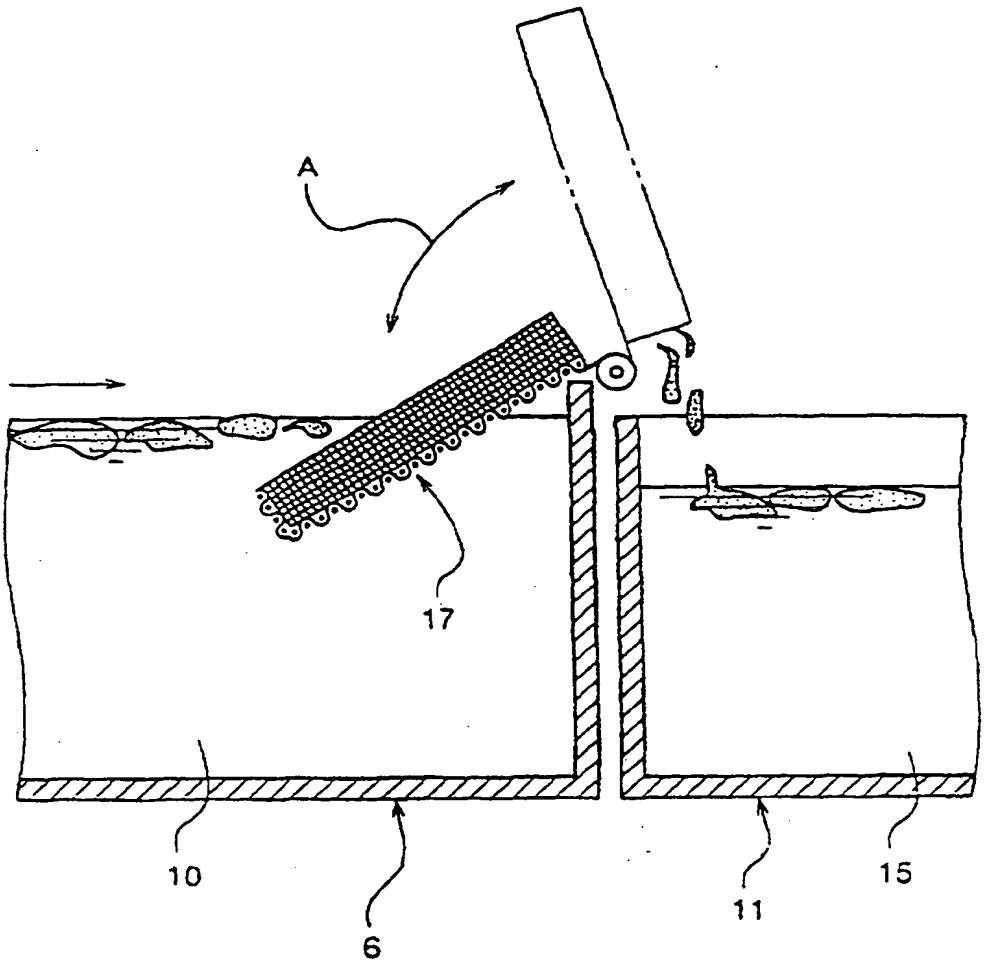
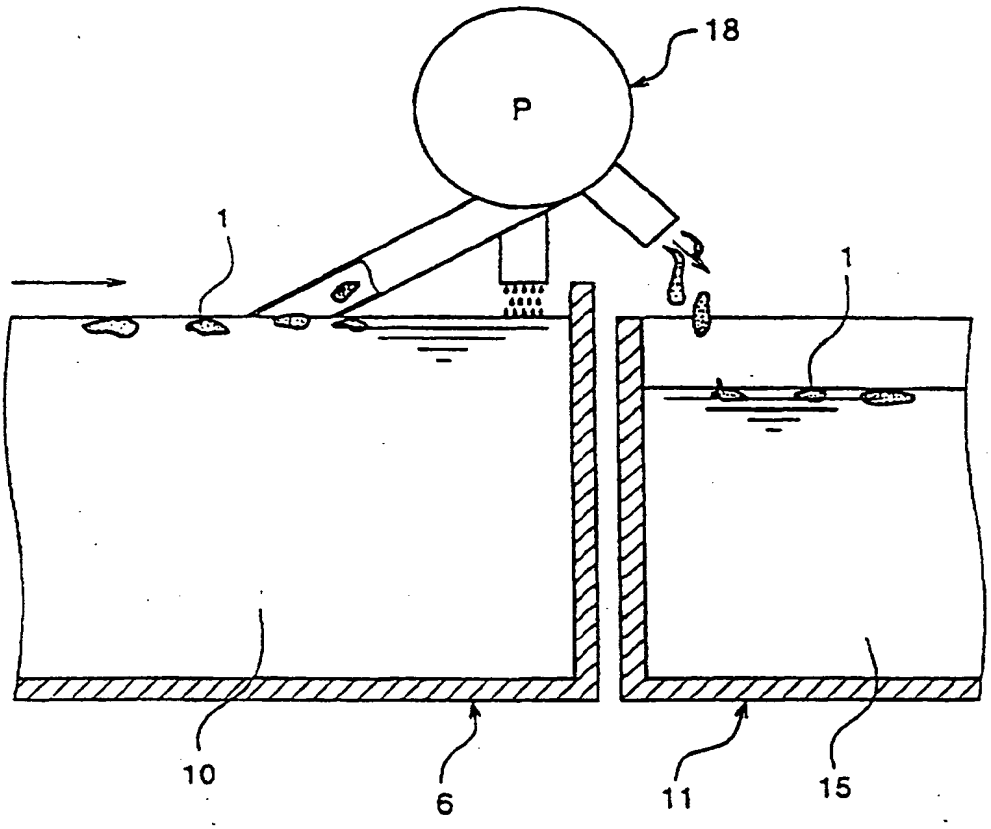


FIG. 4



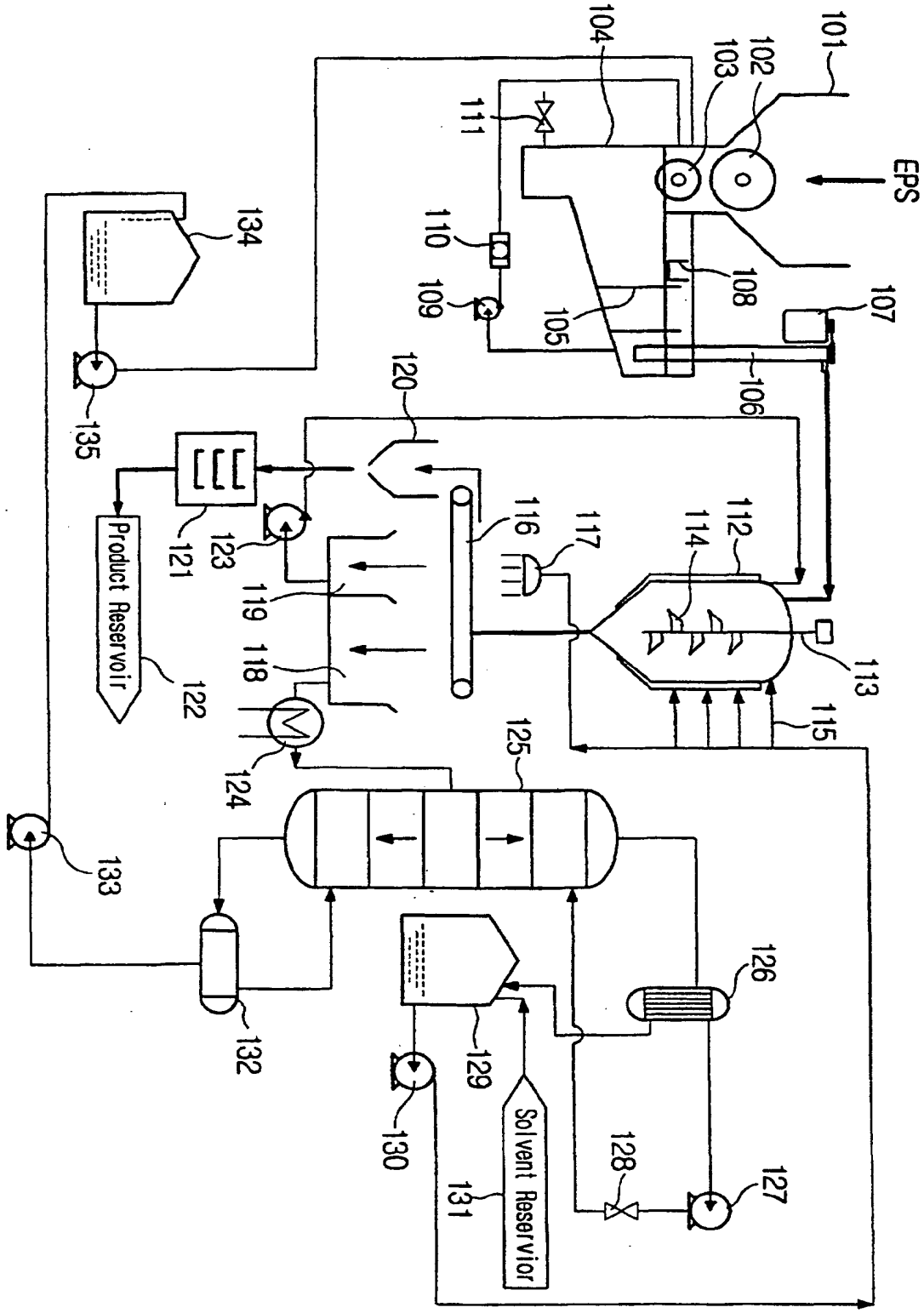


FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 00 31 1307

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 June 2001	Hillebrand, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 00 31 1307

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

[X] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

5-16

[ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

[ ] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

[ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

[ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

[X] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 31 1307

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 June 2001	Hillebrand, G

CATEGORY OF CITED DOCUMENTS

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 00 31 1307

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-4

   First solvent consisting of an dicarbonate diester.

2. Claims: 1-4

   First solvent consisting of a carbonate ester.

3. Claims: 1-4

   First solvent consisting of a nonpolar hydrocarbon.

4. Claims: 1-4

   First solvent consisting of an alcohol.

5. Claims: 1-4

   First solvent consisting of an akylolamine.

6. Claims: 1-4

   First solvent consisting of an alchol.

7. Claims: 1-4

   First solvent consisting of an ester.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 31 1307

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	WO 94 24194 A (SEKITEI AMERICA CORP) 27 October 1994 (1994-10-27) * claim 1 *	6	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 June 2001	Hillebrand, G

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82